REMR TECHNICAL NOTE CS-ES-4.2

COMPUTER PROGRAMS FOR STRUCTURAL STABILITY EVALUATIONS

PURPOSE: To provide guidance about computer programs which can be used to perform the stability analysis of concrete structures.

DESCRIPTION: The programs will analyze the stability of concrete structures. This analysis involves determining the resistance of a structure to overturning, sliding, and base pressures when the structure is subjected to specific applied loadings.

COMPUTER PROGRAMS AND SOME DESCRIPTIONS OF EACH: The computer programs listed below were developed through funds provided the US Army Engineer Waterways Experiment Station (WES) by the Directorate of Engineering and Construction, Headquarters, US Army Corps of Engineers (HQUSACE), under the Computer-Aided Structural Engineering (CASE) project.

A THREE-DIMENSIONAL (3-D) STABILITY ANALYSIS-DESIGN PROGRAM (3DSAD): The computer program 3DSAD was developed to help engineers perform stability analysis-design of general 3-D structures. The program, which is developed in modules, enables the engineer to interact directly with the modules. Descriptions of the modules are as follow:

a. General geometry module. This module performs the following:

   1. Defines geometry based on two-dimensional (2-D) cross sections extended in the third dimension, eight-node brick elements, clusters of planar polygonal and bi-cubic patches, or axisymmetric elements.

   2. Performs centroid, volume, and weight computations on described geometry.

   3. Employs interactive graphics extensively.

b. General loads module: This module computes forces and moments on a general structure based on input force volumes or pressure distributions.

c. General analysis module: This module performs overturning, bearing, and sliding computations.

   Besides the general capabilities that are useful for any 3-D structure, 3DSAD also provides for simplified geometry and load input along with criteria check modules for some specific structures. This latter capability permits interactive design of these structures. Examples of some specific structures for which modules have

been or will be developed are dams, locks, retaining walls, powerhouses, intake structures, and pumping stations.

A "specific" structure input module requires less data than that for a general structure. Modules of this type will interact with the general geometry and general loads modules to define the internal structure forces and moments. After analysis, a "specific" structure criteria check module will validate pertinent allowable values, change dimensions based on user definitions if necessary, and cycle through the computations until computed values meet the allowable values or until maximum user-defined parameters are exceeded. A general schematic of the 3DSAD program is shown in Figure 1.

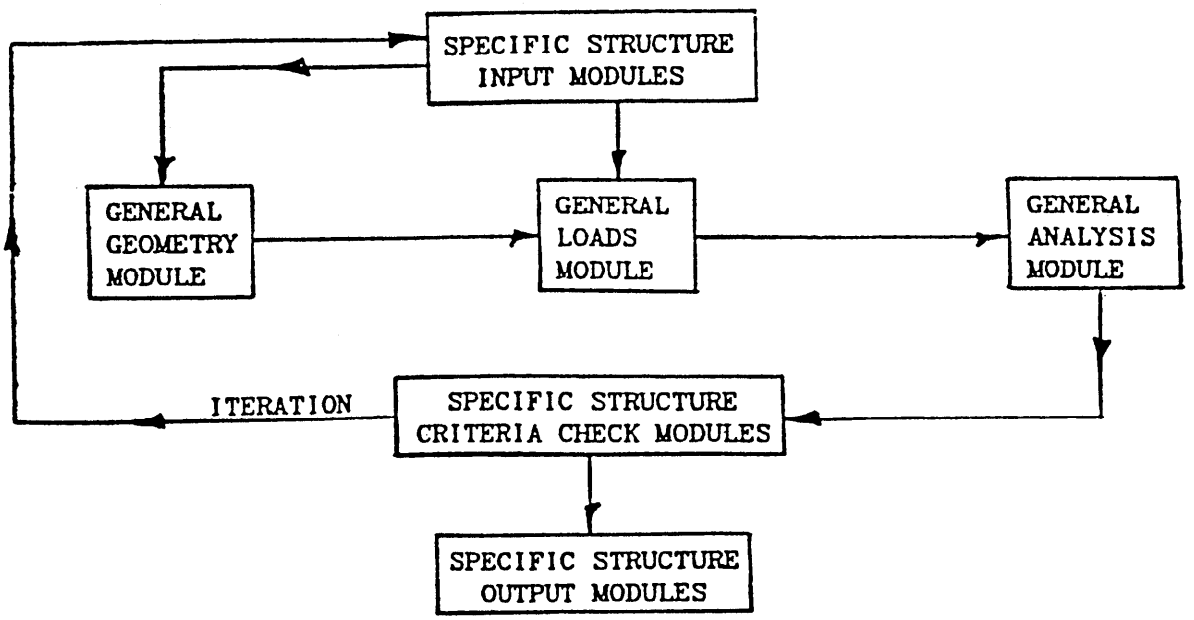

Figure 1. General schematic of 3DSAD

The 3DSAD program was developed in phases. During the first phase, the three general modules were developed; therefore, the stability analysis of any 3-D structure could be performed, although the input was more complicated than that needed for some specific structures. In the second phase, the DAMS and LOCKS input and criteria check modules were developed. In subsequent phases, input and criteria check modules will be developed for other specific structures.

The only "specific" structure input modules that are now running are the DAMS and the LOCKS modules. The LOCKS module is running only on the Harris System in the Mobile District. A more detailed description and information about the use of the computer program 3DSAD can be found in Ref a.

NOTE: The sliding stability computed by 3DSAD is based on the shear-friction theory rather than the limit-equilibrium method as required by ETL 1110-2-256.

SLIDING STABILITY OF CONCRETE STRUCTURES (CSLIDE): CSLIDE was developed to assess the sliding stability of concrete structures using the limit-equilibrium method described in the Engineering Technical Letter (ETL) 1110-2-256.

CSLIDE can compute the factor of safety against sliding attributable to the following:

a. Multiple soil layers with irregular surfaces.

b. Water and seepage effects.

c. Applied vertical surcharge loads, which include line, strip, triangular, uniform, and ramp loads.

d. Applied horizontal point loads.

e. Irregularly shaped structural geometry with either a horizontal or sloped base.

f. A percentage of the base of the structure in compression because of overturning effects.

g. Single or multiple failure planes.

h. Horizontally and vertically induced loads caused by earthquake accelerations.

i. Other factors which may require the user to predetermine the failure surface.

Input data may be supplied interactively from the terminal or from a pre-defined data file. The user can display the results on the terminal or store them in an output file. The output contains the input data used in analysis, the factor of safety, and a summary of failure angles and forces acting on the wedges making the failure surface.

A report in preparation will give a detailed description of computer program CSLIDE and its use.

COMPUTER PROGRAM TWDA: Program TWDA is a computer-aided structural design system for analysis or design of inverted-T cantilever walls founded on earth or rock. Multiple load cases will allow the wall to act as a floodwall or a retaining wall. Structural stability and stress design-analysis are performed by this program.

The program is a series of design or analysis modules or subprograms. Each is controlled as one unit and performs one complete aspect of the purpose of the entire program in the design or analysis process. These modules are callable, in any logical sequence, from an executive command phase which is the central core of the user's flow of control.

While in the executive phase, the user may call various procedures for data entry, data review, saving the current design status, restoring from an old status save, etc. This process is illustrated in Figure 2.

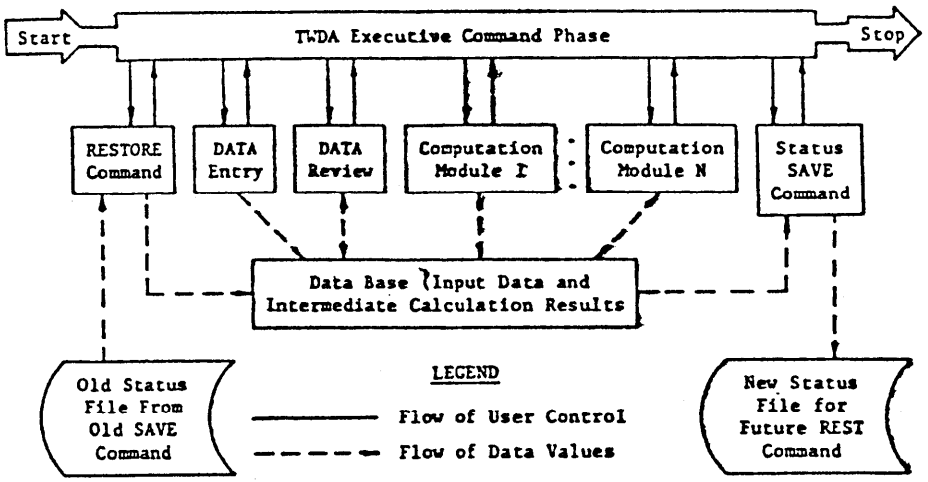

Figure 2. Basic program flowchart

The program has restart capabilities which, in addition to the user-controlled SAVE files, will use an automatic UPDATE file that is reset after the completion of a command or a calculation module.

The RESTart command will restart the program from an old update or saved file.

CALCULATION MODULES: A list of major calculation modules includes:

a. SA--Stability analysis Active pressures for overturning and sliding, calculated along a vertical plane at end of heel.

   Coulomb's equations plus subcharge pressure equations, assuming elastic soil.

   Incremental wedge methods.

   As imputted.

b. FA--Foundation stability Analysis of completely defined wall (overturning, sliding, and bearing); uses module SA as needed.

c. FD--Foundation stability Design; uses modules SA and FA as needed.

d. SP--Stem Pressures for structural analysis. Same basis as module SA, except that the pressures are calculated at the stem face instead of at the end of the heel for structural analysis of the stem. Heel, toe, and key slabs use pressures based on the stability analysis from modules FA or FD.

e. WA--Working stress structural Analysis.

f. WD--Working stress structural Design.

g. UA--Ultimate strength structural Analysis.

h. UD--Ultimate strength structural Design.

A detailed description of TWDA and its use can be found in Ref b.

U-FRAME BASIN AND CHANNEL ANALYSIS PROGRAM: This program has two user guides, one for basins and one for channels. Analysis generally follows EM 1110-2-2400, "Structural Design of Spillway and Outlet Works," 1956. Basins may have up to two intermediate walls, arranged symmetrically. Channels may have one intermediate wall located anywhere. Analysis includes the determination of foundation stability pressures, slab and wall thickness, and the size of required steel reinforcing.

This program, which is designed to perform analysis of a 2-D slice of a U-frame structure, functions in two modes. In Equilibrium mode, input data are converted to pressure distributions, and the resultants are determined for each loading source on each side of the structure. For soil-supported structures, the distribution of base-reaction pressure is determined to equilibrate all loads. Equilibrium of pile-supported structures is assumed to be provided by the pile forces. The Frame Analysis mode formulates a 2-D model consisting of flexible members with rigid blocks at various intersections of the stem and base. Frame analyses consist of deflections, axial forces, bending moments, and shears throughout the flexible segments of the structure. If pile supports are present, pile head forces and results of pile-over-stress comparisons are provided.

UFRAME is written in FORTRAN for operation in a timesharing environment; however, the program's permanent file capabilities help minimize any problems caused by time-sharing. Input graphics, a part of the UFRAME program, depict the structure geometry, soil and water evaluations, soil and water pressure diagrams, and additional user-supplied loads. Output graphics is a separate postprocessor to the analysis program.

REFERENCES:

a. Kling, C. William. 1985 (June). A Three-Dimensional Stability Analysis/Design Program (3DSAD), Report 5, US Army Engineer District, Mobile, Mobile, AL.

b. Price, William A., and others. 1980 (Dec). "Basic User's Guide: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Flood Walls (TWDA)," Instruction Report K-80-6, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

c. Price, William A., and others. 1980. "User's Reference Manual: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Flood Walls (TWDA)," Instruction Report K-80-7, US Army Engineer Waterways Experiment Station, Vicksburg, MS.